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Investigation of NaOH Properties, Production and Sale Mark in the world

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***Abstract*— This paper investigates some kind of properties of NaOH and the Consumption market. Sodium hydroxide (NaOH) is one of the most commonly used laboratory and industrial chemicals. Concentrated sodium hydroxide (also known as lye or caustic soda) causes severe chemical burns of the skin and may damage the cornea of the eye so severely that blindness may result. Sodium hydroxide, for instance, is used in households to pickle old paint and varnishes or as a chemical drain cleaner. Sodium hydroxide is used in detergent and soap production, as well as in the pulp and paper industry. In the food industry, this caustic soda is used to flush the bottles in bottling lines. In the chemical industry, many acids are neutralized using sodium hydroxide.**

***Keywords*— Sodium hydroxide; NaOH market; NaOH production; NaOH uses**

I. INTRODUCTION

NaOH (sodium hydroxide or caustic soda) is a by-product of the chlorine-alkali process. As this process is determined by the long-term demand for chlorine, changes in demand for NaOH does not affect the output of NaOH from this process. An analysis of the NaOH market reveals that long-term changes in demand for NaOH will affect the least essential uses of NaOH, i.e. those uses where NaOH can readily displace sodium carbonate (soda ash). A long-term increase in demand for NaOH will thus be met by increased use of sodium carbonate for those uses where NaOH is not essential, e.g. in pulp and paper, water treatment, and certain chemical sectors where it is used as a neutralizing agent [1]. Likewise, a long-term decrease in demand for NaOH will lead to increased displacement of sodium carbonate. In the current market situation, where there is a global increase in demand for chlorine, the continuously increasing output of NaOH is adequate to cover the applications where NaOH is essential, and a marginal increase in NaOH demand will therefore not lead to a need to produce NaOH from the alternative process route (the caustification process, where NaOH is produced from lime and soda). If there is a further increase in demand for NaOH for essential applications, without a simultaneous increase in demand for chlorine, the caustification process will again be able to play a role as a marginal production route for NaOH, as has been the case previously. To model the current long-term market reaction to a decreased demand for NaOH in a life cycle assessment, we thus recommend using the derived decrease in sodium carbonate supply [2]. Sodium carbonate is currently produced from NaCl and CaCO3 in the Solvay process (in Europe), and in addition directly from naturally occurring ores (trona) or brines (USA). The displaced sodium carbonate supply may, therefore, depend on the location and transport costs. The Solvay process is still the dominating process globally, implying that the output from the naturally occurring sources is not globally competitive and that a decrease in NaOH demand will primarily affect the Solvay process. Sources for environmental data for the Solvay and the trona mining processes are identified [3].

Sodium hydroxide (caustic soda) is highly soluble in water, and sodium hydroxide solutions are strong bases. The annual world production of sodium hydroxide is on the order of 60 million tons. It is universally used as a neutralization agent in the chemical industry, paper making, etc. Soda lye contains in general 30 wt% of sodium hydroxide.

II. CHEMICAL STRUCTURE OF NAOH

Sodium hydroxide, also known as lye and caustic soda, is an inorganic compound with formula NaOH. It is a white solid ionic compound consisting of sodium cations Na+ ion and hydroxide anions OH−. Sodium hydroxide is a highly caustic base and alkali, that decomposes proteins at the ordinary ambient temperatures and may cause severe chemical burns. It is highly soluble in water and readily absorbs wet moisture and carbon dioxide from the air. It forms a series of hydrates $NaOH\cdot nH_2O$ [1, 2]. The monohydrate $NaOH\cdot xH_2O$ (x=1) crystallizes from water solutions between 12.3 and 61.8 °C. The commercially available "sodium hydroxide" is often this monohydrate, and published data may refer to it instead of the anhydrous compound. NaOH is used in many industries in the manufacture of pulp and paper, textiles, drinking water, soaps, and detergents and as a drain cleaner. Worldwide production in 2004 was approximately 60 million tones, while demand was 51 million tones [4].

A. Physical Properties

Pure sodium hydroxide is a colorless crystalline solid that melts at 318 °C without decomposition. It is highly soluble in water, with a lower solubility in ethanol and methanol, but is insoluble in ether and other non-polar solvents. Similar to the hydration of sulfuric acid, dissolution of solid sodium hydroxide in water is a highly exothermic reaction[5] in which a large amount of heat is liberated, posing a threat to safety through the possibility of splashing. The resulting solution is usually colorless and odorless. As with other alkaline solutions, it feels slippery when it comes in contact with the skin due to saponification [6].

B. Crystal structure

The monohydrate crystallizes in the space group Pbca, with cell dimensions a = 1.1825, b = 0.6213, c = 0.6069 nm. The atoms are arranged in a hydrargillite-like layer structure /O Na…O-O… Na O/... Each sodium atom is surrounded by 6 oxygen atoms, three each from hydroxyl anions HO− and three from water molecules. The hydrogen atoms of the hydroxyls form strong bonds with oxygen atoms within each O layer. Adjacent O layers are held together by hydrogen bonds between water molecules [6].

Sodium hydroxide is industrially produced as a 50% solution by variations of the electrolytic chloralkali process. Chlorine gas is also produced in this process. Solid sodium hydroxide is obtained from this solution by the evaporation of water. Solid NaOH is most commonly sold as flakes, prills, and cast blocks [5, 6].

In 2004, world production was estimated at 60 million dry metric tons of sodium hydroxide, and demand was estimated at 51 million tones [5, 6]. In 1998, total world production was around 45 million tones. North America and Asia each contributed around 14 million tons, while Europe produced around 10 million tones. In the United States, the major producer of sodium hydroxide is the Dow Chemical Company, which has annual production around 3.7 million tones from sites at Freeport, Texas, and Plaquemine, Louisiana and Other major US producers. All of these companies use the chloralkali process [7]. Historically, sodium hydroxide was produced by treating sodium carbonate with calcium hydroxide in a metathesis reaction. (Sodium hydroxide is soluble while calcium carbonate is not.) This process was called causticizing [7].

$$Ca(OH)_2(aq)+Na_2CO_3(s)\rightarrow CaCO_3+2NaOH(aq) \quad (1)$$

This process was superseded by the Solvay process in the late 19th century, which was in turn supplanted by the chloralkali process which we use today. Sodium hydroxide is also produced by combining pure sodium metal with water. The byproducts are hydrogen gas and heat, often resulting in a flame, making this a common demonstration of the reactivity of alkali metals in academic environments; however, it is not commercially viable, as the isolation of sodium metal is typically performed by reduction or electrolysis of sodium compounds including sodium hydroxide.

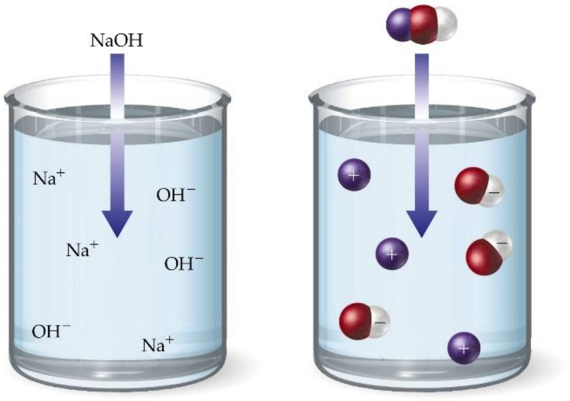

Fig. 1. *The aqueous solution of NaOH*

C. NaOH Uses

Sodium hydroxide is a popular strong base used in the industry. Around 56% of sodium hydroxide produced is used by industry, 25% of which is used in the paper industry. Sodium hydroxide is also used in the manufacture of sodium salts and detergents, pH regulation, and organic synthesis. It is used in the Bayer process of aluminum production [6]. In bulk, it is most often handled as an aqueous solution, since solutions are cheaper and easier to handle [7]. Sodium hydroxide is used in many scenarios where it is desirable to increase the alkalinity of a mixture or to neutralize acids. For example, in the petroleum industry, sodium hydroxide is used as an additive in drilling mud to increase alkalinity in bentonite mud systems, to increase the mud viscosity, and to neutralize any acid gas (such as hydrogen sulfide and carbon dioxide) which may be encountered in the geological formation as drilling progresses.

Poor quality crude oil can be treated with sodium hydroxide to remove sulfurous impurities in a process known as caustic washing. As above, sodium hydroxide reacts with weak acids such as hydrogen sulfide and mercaptans to yield non-volatile sodium salts, which can be removed. The waste which is formed is toxic and difficult to deal with, and the process is banned in many countries because of this. In 2006, Trafigura used the process and then dumped the waste in Africa [8].

D. Sodium hydroxide in the petroleum industry

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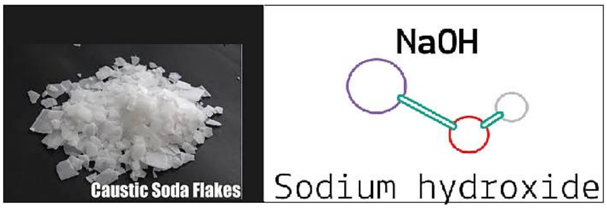

Fig. 2. *Chemical structure of NaOH.*

Nowadays Caustic Soda and Sodium Carbonate are widely used in several industries.

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- It is desirable to increase the alkalinity of a mixture or to neutralize acids.
- Chemical pulping
- Tissue digestion
- Dissolving amphoteric metals and compounds
- Esterification and transesterification reagent
- Food preparation
- Cleaning agent
- Water treatment
- In Cement mixes, mortars, concrete, grouts

E. Market Assessment

Sodium carbonate is an inorganic salt of Sodium and carbonic acid. It is also known as soda ash, soda crystals, and washing soda. Sodium carbonate is a white, odorless, hygroscopic, amorphous solid soluble in water and most solvents. It has an alkaline taste and results in a strongly alkaline solution with water. Sodium carbonate is often utilized domestically as a common water softener. Sodium carbonate occurs naturally across the globe and can be mined for consumption. It can also be manufactured commercially from sodium chloride (common salt) and limestone through the 'Solvay Process'. Sodium carbonate has low toxicity, however prolonged exposure to skin and eyes or inhalation of dust may cause irritation. Ingestion of sodium carbonate may cause vomiting, diarrhea, stomach ache, and nausea. Sodium carbonate releases carbon oxides when reacted with acids or burned.

Sodium carbonate is primarily used by the chemical industry for manufacturing glass, detergents, sodium chemicals, and carbonate chemicals. It is also employed by the paper and pulp industry for paper production. Sodium carbonate is used in industrial and municipal wastewater treatment because of strict regulations requiring dechlorination of the wastewater treatment process. It is also employed for brine treatment, coal treatment and desulphurization of flue gas. Sodium carbonate finds major consumption in industries as well as households for removal of hardness in water and pH adjustment of water. Sodium carbonate is also used as a catalyst for resin regeneration through ion exchange.

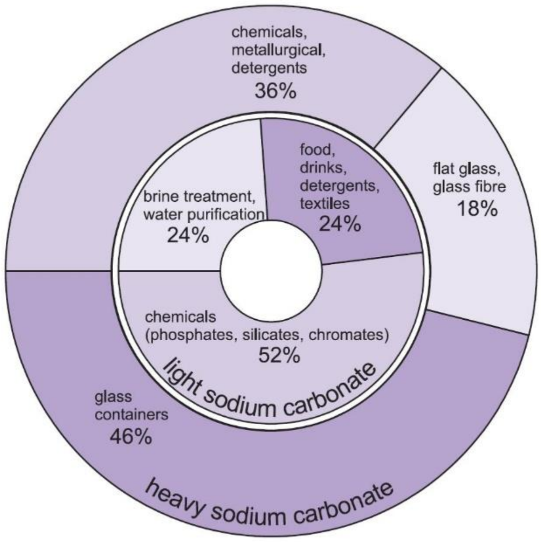

Fig. 3. *Schematic Image of NaOH market.*

Expanding industrial economies of Asia Pacific, Latin America and Africa are expected to bring prospective opportunities for future market growth of sodium carbonate.

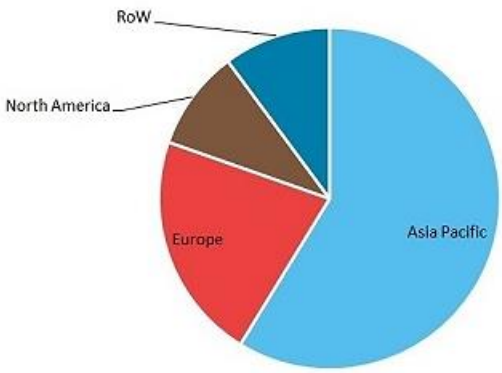

Fig. 4. *Global soda ash demand by region.*

III. Environmental data for soda production

A. The Solvay process

In the Eco-invent database, the Solvay process can be found as Soda, powder, at plant /RER/U The process is documented in Eco-invent report no 8 (Althaus et al. 2003, p. 629). The main data source is UBA (2001), a German report on the best available techniques (BAT) for soda production. This source presents data from 1999 from two German manufacturing plants: Solvay Soda Deutschland, located in Rheinberg and a production plant from the company Matthes and Weber, in Duisburg. The latter gave up the production at the end of the year 1999, but for the purpose of this study, their data are also considered. Additional information is taken from Thieme (1993), KCL (2002) and Woode (1995). In this latter, each chapter is written by an industry expert. The disadvantage of this source is that it does not mention the origin of the values reported. To be used for soda, all values of the Eco-invent process shall be multiplied by 3, since the original data are allocated with 33% to Soda and 76% to calcium chloride [9, 10, 11].

B. Effects on human health

Humans can be exposed during the manufacture of sodium hydroxide and in the handling of sodium hydroxide as a solid or concentrated solution. Sodium hydroxide is corrosive to all body tissues; concentrated vapors cause serious damage to the eyes and respiratory system. Ingestion of sodium hydroxide, which occurs frequently in children, can cause severe necrosis, with stricture of the esophagus and death. Contact with the skin can result in dermatitis, loss of hair, and necrosis due to irritation. Skin types vary in sensitivity to caustic irritation.

IV. Conclusion

NaOH is usually dispensed as semi-spherical pellets. Caustic substance and skin contact should not be avoided. It is hygroscopic (ie will absorb water from the air when exposed). This means that an accurate, dry weight is difficult to determine. sodium hydroxide, when exposed to the air, will react with the carbon dioxide in the air, to form sodium carbonate. This means that sodium hydroxide as a solid or in solution will lose its strength with time and the degree of exposure and solutions of NaOH will need to be standardized. Also the sodium carbonate market is primarily driven by its demand in water treatment applications, paper and pulp applications and applications in chemical industry. However, difficult disposal of effluents from the production process and stringent regulations for effective waste management might hamper market growth.

References

[1] B. Kumfer, C.Felch, and C.Maugans, “Wet Air Oxidation Treatment of Spent Caustic in Petroleum Refineries”, the National Petroleum Refiners Association Conference Phoenix, AZ; March 21-23, 2010.

[2] P. R. Siemens, William F. Giauque, "Entropies of the hydrates of sodium hydroxide. II. Low-temperature heat capacities and heats of fusion of NaOH·2H2O and NaOH·3.5H2O". Journal of Physical Chemistry, volume 73, issue 1, pp. 149–157, 1969.

[3] C. Kurt, J. Bittner "Sodium Hydroxide", Ullmann's Encyclopedia of Industrial Chemistry, Weinheim: Wiley, 2000.

[4] A. Waqar, “Neutralization of Spent Caustic from LPG Plant at Preem AB Göteborg”, Ms.c Thesis in Chemical and Biological Engineering, Göteborg, Sweden, 2010.

[5] T. H. Leon, K. Justin, “Carcass Disposal: A Comprehensive Review”. Chapter 6. National Agricultural Biosecurity Center, Kansas State University, 2010.

[6] W. A. Mohammed, N. M. T. Abbass, “Preparation of Sodium Hydroxide by Using Natron and Quick Lime”. Diss. Sudan University of Science and Technology, 2014.

[7] M.V. Reboucas, “Analysis of Effluent from caustic Treatment Plants”, Institute Colombiano del Petroleo, Colombia, pp. 163-170, 2006.

[8] H.J. Althaus, M. Chudacoff, R. Hischier, N. Jungbluth, M. Osses, A. Primas, “Life Cycle Inventories of Chemicals”. Final report ecoinvent, Volume: 8. Swiss Centre for LCI, EMPA-DU. Dübendorf, CH, 2003.

[9] M. Amini and A. Khavandi, 2019. Degradation of polymer-based composites in corrosive media: experimental attempts towards underlying mechanisms. Mechanics of Time-Dependent Materials, 23(2), pp.153-172.

[10] B. P. Weidema, “Market information in life cycle assessment”. Copenhagen: Danish Environmental Protection Agency. (Environmental Project no. 863), 2003.

[11] M. Amini and A. Khavandi, 2019. Synergistic effects of mechanical and environmental loading in stress corrosion cracking of glass/polymer composites. Journal of Composite Materials, 53(24), 3433–3444.

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